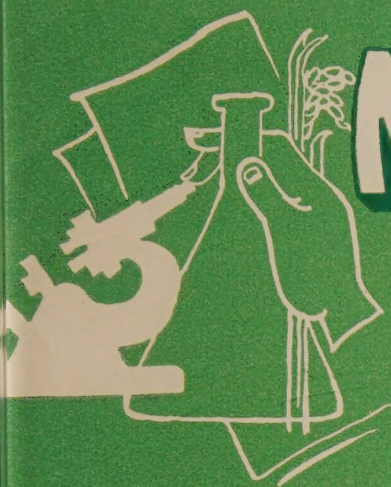


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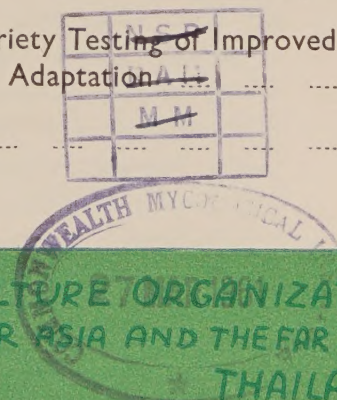
December, 1960

## CONTENTS

	Page
Correlation between Soil Analyses and Responses to Fertilizers with Special Reference to Rice Crop in India .....	
<i>R.V. Tamhane &amp; B.V. Subbiah</i>	1
What Fertilizers could do to Increase World Food Production .....	
<i>H.L. Richardson</i>	11
Rice in Thailand .....	
<i>Sala Dasananda</i>	23
The Cultivation of Upland Rice in Rotation with Groundnut in Senegal .....	
<i>C. Magne</i>	30
Plans for Cooperative Variety Testing of Improved Rice Varieties with Wide Adaptation .....	
<i>M.M.</i>	34
Announcement .....	36



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# CORRELATION BETWEEN SOIL ANALYSES AND RESPONSES TO FERTILIZERS WITH SPECIAL REFERENCE TO RICE CROP IN INDIA

R.V. Tamhane & B.V. Subbiah<sup>1</sup>

## Introduction

The farmers in all the progressive countries of the world are becoming increasingly aware of the need to have soils tested for evaluation of their fertility status and prediction of the amount of different fertilizers to be used. If soil tests are to be dependable they must carefully be calibrated against crop responses to fertilizers in field experiments. Thus, the development of a soil testing service is a long drawn out process of research involving gradual accumulation of data concerning the behaviour of individual nutrients in different soil types and for different crops. With the recent establishment of soil testing laboratories in India, this type of research work is of great importance and practical utility and it is proposed to give an account of the work being carried out on the soil test - crop correlation work in respect of P, K and N, with special reference to the rice crop.

## Phosphate

In the past, use of chemical extractants for estimating available phosphate and assessing the need for phosphate fertilizers or otherwise has been reported by some workers and out of different methods, Dyer's method received the greatest attention. Leather (1907) working on some representative Indian soils obtained the limits of phosphate response to be below 0.005% except in the case of

laterite soils in which a much higher limit of 0.011% was obtained. In calcareous soils, Das (1926) found extraction with  $K_2CO_3$  to give more satisfactory results for phosphate than with other dilute acid extractants. These earlier studies lacked systematic attempts to correlate analytical results with the crop responses. A large number of soils in rice growing areas has been analysed earlier in many States of this country but attempts at the correlation with crop response have been very few.

In recent years, intensive work has been carried out in India to evaluate the methods for estimating available phosphates for determining the limits of response or lack of response. Using several extractants, Raychaudhuri, Subbiah and Sinha (1954) reported that correlation, significant at 1% level, was obtained between paddy crop responses to phosphatic fertilizers and available phosphate by Truog's method and the next high correlation, significant at 5% level, was obtained with Bray's method in red and lateritic soils of Bihar. Later, Datta & Kamath (1958) carried out intensive investigations on Indian soils in both pot culture and field experiments and found that for many soils available phosphate by Olsen's method gave high correlations with crop responses in the case of paddy crop. The correlation coefficients of soil test values for phosphorus by various methods and

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% yield responses<sup>1</sup> in pot culture and field experiments on paddy as obtained by different workers are given in Table I. On the basis of their work, Datta & Kamath (1958) fixed the limits for low, medium and high values for paddy for the available  $P_2O_5$  by Olsen's method as follows: low—less than 20 lbs, medium—21-50 lbs and high—above 50 lbs per acre. These are practically the same as suggested by Olsen (1954). Further work by Tamhane, Subbiah & Bajaj (1958) showed that the available phosphate by Olsen's method and phosphorus uptake by paddy crop in control pots were highly correlated ( $r=0.781$ ) and this relationship could be expressed by the equation  $Y = 2.32 + 0.377 X$ , where Y represents the phosphorus uptake in mgs. per pot and X represents the available phosphate in lbs/acre by Olsen's method.

### Potassium

Stewart (1947) remarked "The general experimental evidence appears to suggest that most Indian soils apart from laterites are relatively well supplied with potash and that for most crops there is very little need for potassic fertilizers." Recent experiments in Bihar by Mukerjee (1955) and Potascheme (1955) indicate that potash applications to paddy are likely to prove profitable in Bihar, Andhra, Assam, Orissa, Kerala & Mysore.

Leather using Dyer's 1% citric acid method reported that potash responses were only slight in Indian soils even with 0.0023% available  $K_2O$ . Sen, Deb & Bose (1949) found that all laterite soils which were studied by them with very few exceptions contained much less

than 15.00 gms. of exch. K per 100 gms. of soil and that they were likely to respond to K fertilizer. Mukerjee, Mandal and Mukherjee (1955) from a study of the 1% citric acid soluble and exch.  $K_2O$  of Bihar soils showing response and no response to K fertilisation, concluded that percentage K saturation appeared to be a more reliable index for K response than the net amount of exch. K. Mitra, Sharma and Ramamoorthy (1958) found that responses of rice to K fertilisation were related more to K availability based on geological origin of the soil than to a single chemical test which does not take seasonal variation in K availability into account.

In pot culture experiments (Oommen 1959) reported that none of the extractants have given any significant correlation on all India soils. However, when the soils were separated on their textural basis as light soils, medium soils and heavy soils, light soils gave high correlation ( $r = 0.93$  significant at 1% level) between percentage K saturation value and paddy crop responses to potassium. Further examination of the soils showed that soils having montmorillonite clay mineral gave little response to application of K fertilizers while those having kaolinitic clay mineral showed responses.

Work carried out by Tamhane, Subbiah & Oommen (1957) showed that no single extractant is likely to be suitable for all the soils in India and exchangeable K as determined by ammonium acetate did not appear to be a good index of the soil's capacity to supply potassium. Potassium extracted by Morgan's extractant, percentage K saturation and dilute nitric acid

<sup>1</sup> (Percent yield =  $\frac{\text{yield without } P_2O_5 \text{ fertilizer} \times 100}{\text{yield with adequate } P_2O_5 \text{ fertilizer}}$ )



**TABLE I**  
*Correlation Coefficients of Soil Test Values for Available Phosphorus by Various Methods and Percentage Yield Response in Pot Culture and Field Experiments on Paddy as obtained by Various Workers in India.*

Method	Extractant	r Values			
		Pot Culture Experiments	Field Experiments		
		All India Soils (3 years average)	All India Soils	Red and Laterite Soils from Bihar	
1. Truog's method	0.002N H <sub>2</sub> SO <sub>4</sub> buffered to pH 3.0 with amm. sulphate	0.36*	+0.16	-0.52	-0.46**
2. Bray's method I (1945)	0.1N HCl*.03N NH <sub>4</sub> F	-0.27	-0.82**	-0.11	-0.44*
3. Bray's method II (1945)	0.025N HCl*.03N NH <sub>4</sub> F	-0.48**	-0.66*	-0.22	-0.04
4. Olsen's method (1946)	0.5M NaHCO <sub>3</sub> , pH 8.5	-0.76**	-0.69	-0.52*	-0.16
5. Morgan's method (1950)	Sodium acetate & acetic acid, pH 4.8	-0.48**	+0.29	-0.19	-0.03
6. Dyer's method (1894)	1% citric acid	-0.57**	-0.71*	-	-
7. McGeorge & Pearson (1947)	Carbon dioxide	-0.49**	-0.58	-	-
		(Datta & Kamath 1958)	(Datta & Kamath 1958)	(Sinha, Subbiah & Raychaudhuri 1954)	

\* Significant at 5% level

\*\* Significant at 1% level



soluble potassium showed moderately good correlation with crop response to potassic fertilizers in red and laterite soils of Bihar, acid alluvial soils of Kerala and west coast alluvial soils of Mysore respectively. The correlation coefficients between soil test values by various methods and crop responses to fertilizers as obtained by different workers are given in Table II.

According to recent literature, variation in moisture may account for considerable changes in the availability of potassium. Further correlation work will have to be carried out taking into consideration these moisture relationships.

## Nitrogen

As pointed out by Fitts and Nelson (1956), the increasing awareness of the importance of nitrogen in crop production has led many workers in recent years to evaluate the capacity of soils to supply nitrogen. Richardson (1952) working at Rothamsted reported that mineralisable nitrogen produced under standard conditions was inversely correlated with the responses to nitrogen fertilizers and that the relationship was as good as that obtained for phosphate or potash when the usual methods for available nutrients are compared with fertilizer responses.

Although the organic nitrogen content which makes up about 99% of the total nitrogen in soil, is relatively constant, the rate of change of organic nitrogen to forms that may be absorbed by plant roots is of more importance for correlation with crop growth. The incubation methods recently proposed by Stanford & Hanway (1955) have shown

good correlation with crop responses in arable soils, but in paddy soils, nitrification could be hardly an index of the availability of nitrogen.

In India, in the past, the nitrogen status was evaluated on the basis of the total nitrogen values. In recent years, attempts were made to characterise the nature and decomposibility of organic nitrogen by using alkaline permanganate as the reagent and a method was developed using 0.32% potassium permanganate and 2.5% sodium hydroxide (Subbiah & Asija 1956). The available nitrogen values by this method were well correlated with the total mineralisable N obtained by standard incubation method and paddy yield responses. The coefficients of correlation reported by these workers on paddy crop between available nitrogen and crop response is given in Table III. This was further confirmed by Tamhane, Subbiah & Bajaj (1959) who showed that high correlations could be obtained by this method and paddy crop response in all India soils. The coefficient of correlation between available nitrogen by the permanganate method and percent yields of paddy on all India soils was 0.856 which was significant at 1% level. The percent yield was related to the soil test values of available nitrogen by the equation  $Y = 2.18 + 0.225 X$ , where Y represents the percent yield and X represents the soil test value for available N in lbs per acre. The uptake of N by paddy crop was very highly correlated (coefficient of correlation 0.989) and the uptake of N was related to the available N in the soil by the equation  $Y = 0.532X - 25.75$ , where Y is the nitrogen uptake in mgms. per pot and X is the available nitrogen in lbs/acre.



Recent studies of Subbiah and Bajaj (1958) showed that ammonia release under water logged conditions after one week's incubation may be a better index of nitrogen availability than the available nitrogen values obtained by other methods. The correlation obtained by ammonia release with crop response to paddy was 0.79 in pot culture experiments on all India soils and this was higher than correlation coefficient obtained with available N by alkaline permanganate method ( $r = 0.70$ ). However this method will require careful standardization because of the possible losses of ammonia in certain soils during incubation.

According to alkaline permanganate method, soils with less than 250 lbs/acre N

show good response to nitrogen while above 250 lbs/acre only moderate responses are obtained. Soils above 500 lbs/acre N may be expected to give no response to addition of nitrogen fertilizers for paddy.

### Soil Test Summaries for Paddy Soils in India

With the recent establishment of 22 soil testing laboratories throughout the country, it has become possible for the first time to collect large data on nutrient status of paddy soils. More than 50,000 soils have been analysed during the three years (1956-59) on all India basis. The soil test summary data (vide Table IV) of samples of paddy soils of Andhra, Bihar, Bombay, Kerala, Madras, Mysore,

TABLE II

*Correlation Coefficients of Soil Test Values for Potassium by Several Extractants and % Yield Response in Pot Culture and Field Experiments on Paddy as obtained by Various Workers.*

Method & Extractant	r Values				
	Pot Culture Experiments		Field Experiments		
	All India Soils	All India Clay Loam Soils	Red & Lateritic Soils of Bihar	Acid Alluvial Soils of Kerala	W. Coastal Alluvial Acid Soils
1. Morgan's Extractant	-0.26	-0.38	-0.48*	-0.64	-0.22
2. 0.5N HNO <sub>3</sub> (½ hr shaking)	-0.05	-0.35	-0.23	—	-0.53
3. 0.5N HNO <sub>3</sub> (1 hr shaking)	-0.12	-0.12	-0.34	-0.64	-0.79**
4. Dyer's method (1% citric acid)	-0.10	+0.18	-0.25	-0.65	-0.14
5. Neutral amm. acetate	-0.13	-0.36	-0.21	-0.64	-0.64
6. Exchanged K% values	-0.07	-0.97**	-0.30	-0.81**	—
	(Oommen 1959)	(Oommen 1959)	(Tamhane, Subbiah & P.K. Oommen 1957)		

\* Significant at 5% level

\*\* Significant at 1% level

TABLE III

*Correlation Coefficient of Soil Test Values for Available Nitrogen by Various Methods and % Yield Responses in Pot Culture and Field Experiments on Paddy as obtained by Various Workers.*

Method & Extractant	r Values		
	Pot Culture Experiments		Field Experiments
	All India Soils (1st Experiment)	All India Soils (2nd Experiment)	Red & Laterite Soils of Dumka Alluvial Soils of Panjab Indo-Gangetic
1. Alkaline Permanganate method	-0.70**	-0.86**	-0.52** -0.47**
2. Rapid Iowa Nitrication method	-0.48*	-0.67*	-0.27 -0.24
3. Richardson's modification of Olsen's method	-0.36	-0.80*	-0.15 -0.15
4. Ammonia Production under water logged condition	-0.79**	-	-
5. Standard Incubation method	-	-0.81**	-0.57** -
6. Organic Carbon (Walkley & Black's method)	-	-0.78** (Tamhane, Subbiah & Bajaj) 20 soils	-0.35** (B.V. Subbiah & J.C. Bajaj) 28 soils

\* Significant at 1% level

\*\* Significant at 5% level



Orissa and W. Bengal is given (vide fig. 1) along with the all India soil test summaries (Table V) for comparison. The predominant rice growing areas of India may be divided into (1) the Eastern zone comprising of Bihar, W. Bengal, Orissa, Assam and Tripura; (2) the Southern zone comprising of the States of Andhra, Mysore, Madras and Kerala. In both these zones, red and lateritic soils predominate together with some alluvial soils. The main features of red soils (Soil Survey final report 1953) are lighter texture, porous and friable structure, absence of calcium carbonate nodules and free carbonates and low soluble salt content. The clay fraction of the red soil is rich in Kaolinitic type of mineral. The laterite and lateritic soils are peculiar to India and some other countries with intermittent moist climate. These are

characterized by compact to vesicular rock composed essentially of a mixture of the hydrated oxides of Al, and Fe with small amounts of  $MnO_2$   $TiO_2$ , etc. The soil test summaries of these areas indicate that as compared to all India averages, the paddy soils are lower in available phosphate and potassium. Amongst the two regions, the Southern zone soils are poorer than the Eastern zone soils. In the Southern zone, the available phosphate is low in 59% of the soils, medium in 24% and high in 17%. The nitrogen status in the areas is generally low and about 80 to 90% are in the low to medium categories. These summaries prepared on area basis show the general fertility levels and are of value to local agricultural extension workers as they provide basis for estimating the fertilizer need in each area or areas.

TABLE IV

*All India Soil Test Summary for Paddy Soils (State-wise)*

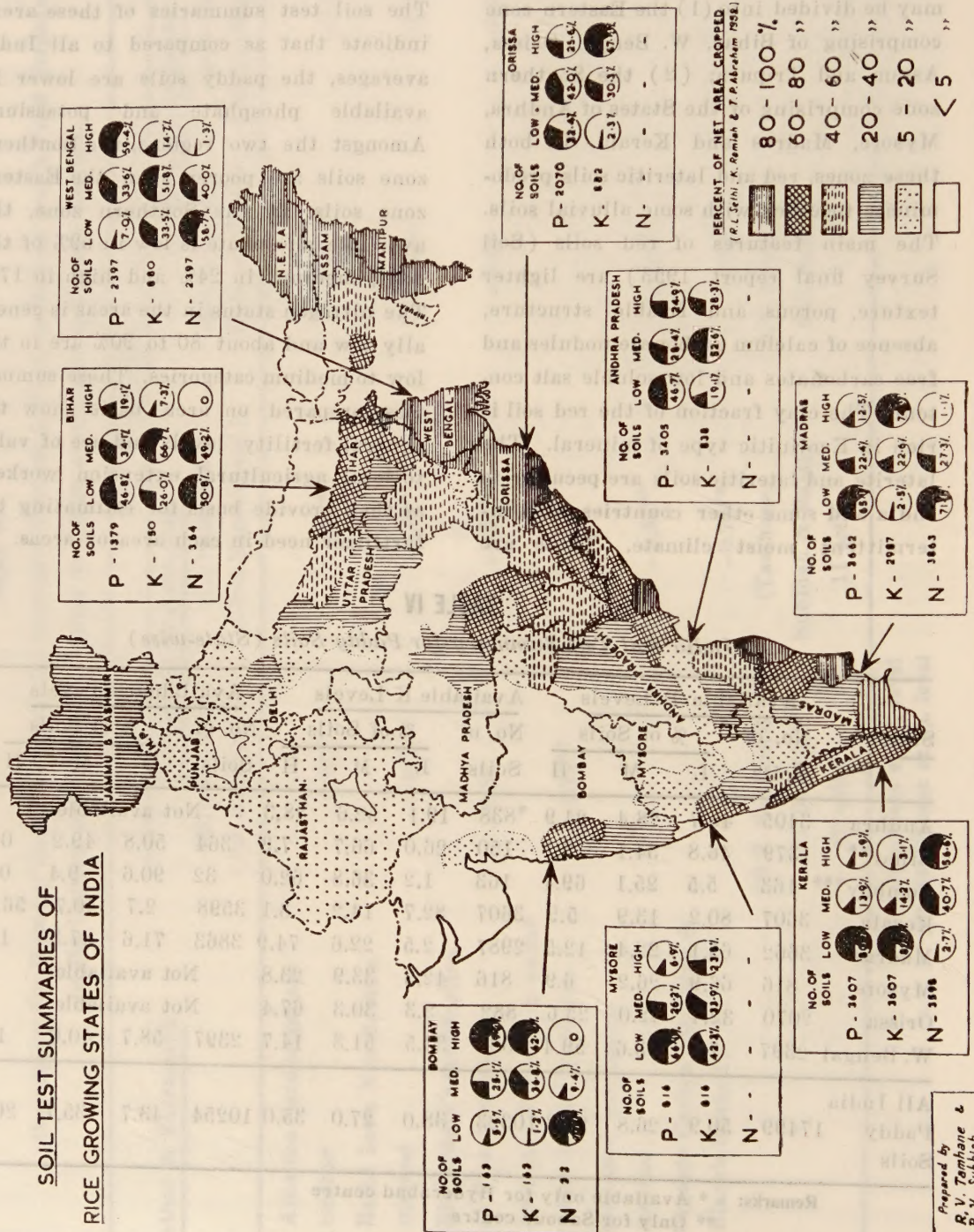
State	Available P Levels				Available K Levels				Available N Levels			
	No. of Soils	% of Soils			No. of Soils	% of Soils			No. of Soils	% of Soils		
		L	M	H		L	M	H		L	M	H
Andhra	3405	46.7	28.4	24.9	*838	19.1	52.6	28.3	Not available			
Bihar**	1379	46.8	34.1	19.1	150	26.0	66.7	7.3	364	50.8	49.2	0
Bombay***	163	5.5	25.1	69.4	163	1.2	36.8	62.0	32	90.6	9.4	0
Kerala	3607	80.2	13.9	5.9	3607	82.7	14.2	3.1	3598	2.7	40.7	56.6
Madras	3662	65.1	22.4	12.5	2987	2.5	22.6	74.9	3863	71.6	27.3	1.1
Mysore	816	66.9	26.2	6.9	816	42.3	33.9	23.8	Not available			
Orissa	2070	32.4	42.0	25.6	882	2.3	30.3	67.4	Not available			
W. Bengal	2397	7.0	33.6	59.4	880	33.5	51.8	14.7	2397	58.7	40.0	1.3
All India Paddy Soils	17499	50.9	26.8	22.3	10323	38.0	27.0	35.0	10254	43.7	35.7	20.6

Remarks: \* Available only for Hyderabad centre  
 \*\* Only for Sabour centre  
 \*\*\* Only for Poona centre



Figure 1

# SOIL TEST SUMMARIES OF RICE GROWING STATES OF INDIA



Prepared by  
R. V. Tamhane &  
B. V. Subbiah



**TABLE V**  
*All India Soil Test Summaries and Nutrient Index Values (State-wise) upto 31.3.59*

State	Available P Levels					Available K Levels					Available N Levels				
	No. of Soils		% of Soils		Nutrient Index	No. of Soils	% of Soils		Nutrient Index	No. of Soils	% of Soils		Nutrient Index	No. of Soils	Nutrient Index
	L	M	H				L	M	H		L	M	H		
Andhra	8081	52.9	22.9	24.2	1.71	*2840	20.7	55.1	24.2	2.03	Not available				
Bihar	2162	43.3	33.3	23.4	1.80	② 191	36.1	35.5	8.4	1.72	675	64.4	35.6	0.0	1.36
Bombay	6136	37.9	41.7	20.4	1.83	2313	9.7	39.3	41.0	2.31	4770	88.9	10.8	0.3	1.11
Delhi	4775	28.0	30.6	31.4	2.03	2565	28.2	56.0	15.8	1.88	Not available				
H.P.	4062	2.2	14.0	83.8	2.82	4062	13.9	55.4	30.7	2.17	4056	32.2	62.1	5.7	1.74
Kerala	4979	73.7	15.3	11.0	1.37	4979	84.8	12.7	2.5	1.18	4949	4.4	42.8	52.8	2.48
Madras	7546	58.9	25.8	15.3	1.56	6626	3.4	22.1	74.5	2.71	7702	78.0	21.0	1.0	1.23
M.P.	4495	24.9	33.6	41.5	2.16	1796	0	10.0	90.0	2.90	4496	97.7	1.5	0.8	1.03
Mysore	2983	66.3	24.0	9.2	1.42	2983	28.1	38.9	33.0	2.05	***1199	21.7	70.0	8.3	1.87
Orissa	2329	34.4	41.4	24.2	1.90	917	2.3	29.9	67.8	2.66	Not available				
Punjab	5754	29.1	41.9	29.9	2.0	**2038	28.2	50.0	21.8	1.94	5059	92.7	6.4	0.9	1.08
W. Bengal	2674	7.4	32.0	60.6	2.53	984	33.0	50.9	16.1	1.83	2674	60.4	38.1	1.5	1.41
Community															
Project Areas	1815	26.8	40.4	32.8	2.06	1721	39.6	51.3	9.1	1.70	1492	63.9	30.8	5.3	1.31
All India Soils	57791	40.4	30.3	29.3	1.89	34015	26.6	37.1	36.3	2.10	37112	65.0	26.2	8.8	1.44

Explanation for Nutrient Index Values: The Nutrient Index Values represent the nutrient status of the whole area as a single value for comparing the fertility status. A value of 1 represents low status, 2 represents medium and 3 represents high status.

Limits Used: (in lbs/acre)

Phosphate	Potash	Nitrogen
L 20	100	250
M 50	250	500
H above 50	above 250	above 500

Remarks ② Available only for two districts  
 \* Data from Hyderabad centre  
 \*\* Available only for Nabha centre  
 \*\*\* Available only for Balehonnur centre



## Conclusions and Future Lines of Development

The preliminary work carried out in India on correlations between soil test values and paddy crop responses to fertilizer application indicated that Olsen's method using sodium bicarbonate as the extractant for neutral and alkaline soils and Bray's & Truog's method for acid soils appeared to be suitable for basing the recommendations on the need or otherwise of the phosphatic fertilizers. For potassium, no single method was found to be suitable although % K saturation values and K extracted by dilute nitric acid and Morgan's extractant appear to give fair indications regarding the available potassium status of different areas of the country. For nitrogen, the use of alkaline permanganate method appears to be useful for paddy soils in determining the extent of nitrogen deficiency.

It will however be clear that systematic correlation work between soil tests and paddy crop responses has been started only recently and is in the initial stages. Although some general correlations have been obtained on all India basis, yet it will be necessary to work out detailed correlations between the soil test values and actual increases in yields on a regional basis which will be of immense use for making definite recommendations for fertilizer application. There is a growing need for having more intensive work in this direction so that the fertilizer advice given to the farmers can have a sound basis.

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## WHAT FERTILIZERS COULD DO TO INCREASE WORLD FOOD PRODUCTION<sup>1</sup>

H.L. Richardson<sup>2</sup>

I need not go into the reasons which made me take up the study of this subject, because they will be self-evident. Today every thinking person knows that the rapid increase in the world's population raises serious problems of food supply, especially in the less-developed countries, and that these problems are likely to become worse in the future. This is why a whole Symposium is being devoted to the subject at the present Meeting of the British Association.

For my part I am placing the emphasis on fertilizers, but I fully realise that they are only one factor in agricultural development. When farming is being improved, many other matters besides fertilizers require and get attention. It is obvious that good crops cannot be grown without adequate supplies of moisture; that selected and tested new varieties will give better yields than the old ones; that improvements in cultural methods and farming systems, including mixed farming and more production of local manures, will make still higher yields possible; and that crops have to be protected from weeds, pests and diseases.

It is further true that these improved techniques can do relatively little to raise average yields, on most soils, without chemical fertilizers; whilst fertilizers can do much more with the help of such improvements than they would be able to alone. There is what statisticians

would call a positive interaction, and we cannot wholly isolate the effect of fertilizers from that of other factors.

In studying population and food problems we are looking ahead: we are concerned not only with what fertilizers can do to increase food production now, but with what they could do in the future. We may start by studying the results of the large-scale schemes of fertilizer field trials that have been carried out in many parts of the world, but this is only a beginning.

In the less-developed countries such trials are done, quite rightly, on the farms of peasant cultivators who are using primitive or traditional farming methods. With inexperienced farmers and unimproved crop varieties it is best to start by using fertilizers at low rates of application, and even so, other factors also limit fertilizer responses. Consequently a study of the results of these experimental programmes leads to rather modest estimates of what fertilizers can do to increase crop yields. We must then go on to examine what fertilizers could do, along with other major improvements, when the traditional agriculture of a country is being developed and modernized as it surely will be.

In this way I have studied the effects of fertilizers in a number of representative, agriculturally less-developed countries where large schemes of fertilizer trials and experiments have been

<sup>1</sup> Speech delivered at the British Association for the Advancement of Science, Annual Meeting, 1960.

<sup>2</sup> Officer of the Imperial Chemical Industries Limited, London.



carried out: namely, China, India, Ghana and Mexico. For an independent check on the conclusions reached, I have also examined the history of crop yields in England, Japan and Formosa; and yet another check is given by comparing the yields secured at agricultural research stations in under-developed countries with those of the peasant cultivators in the surrounding country.

Before going further into these other findings, I shall discuss the results of the fertilizer programmes in the countries first mentioned. The crops selected for study are as far as possible the chief cereal crops in each country, and they are thus the chief sources of the home food supplies. I have not forgotten that tubers, fruits and vegetables are also valuable sources of food, and that livestock, which require grassland and forage crops, provide important food needs, but there is not time to include them as well. It is enough to say here that the other crops and grassland frequently show even larger responses to fertilizers than do the cereals, so that omitting them from consideration is not likely to result in the effects of fertilizers on food production being over-estimated.

## FIELD EXPERIMENT RESULTS IN INDIVIDUAL COUNTRIES

### Possibilities in China: (A) Rice

Before and during the last war, large programmes of fertilizer field experiments were carried out in China, and I have already summarized the results in other publications. The over-all averages from nearly 300 rice experiments showed a total fertilizer response of 755 lbs. of rough or paddy rice per acre, the average

yield without fertilizers being 2,100 lbs. per acre. (This is a high yield figure for unfertilized rice, because the fertility of Chinese soils has been built up through the centuries by the traditional use of local organic manures). The average direct response to fertilizers, used at rates close to  $\frac{1}{2}$  cwt. each of nitrogen, phosphate ( $P_2O_5$ ) and potash ( $K_2O$ ) per acre, was thus 36 per cent.

Although Chinese farming is efficient at a traditional level, and the soils are moderately fertile, there is still room for improvement in crop varieties, cultural methods, and pest and disease control. From experience in China, Japan and Formosa, I would put the average effects of such improvements, including their interactions with fertilizers, at around 15 per cent for better crop varieties, 15 per cent for cultural methods including water control, and 10 per cent for pest and disease control, giving a total increase of 40 per cent. In some localities much larger benefits might be expected, but elsewhere the rice-growing methods are already so good that there is little room for further improvement, except with much heavier manuring, and 40 per cent seems a fair general figure.

Adding this to the 36 per cent for direct response to fertilizers, already mentioned, we get a 76 per cent, or three-fourths, increase in yield as the over-all result from using fertilizers, at  $\frac{1}{2}$  cwt. of each plant food per acre where needed, along with other technical improvements. The average rice yield in mainland China, in the last years for which dependable statistics are available, was 2,330 lbs. of paddy rice per acre, so that the improved yield on this basis would be 4,100 lbs. per acre.



By modern standards the rates of fertilizer application used in the Chinese field experiments were only moderate ones; in Japan and Formosa, where rice-growing conditions are nearest to those in China, the rice farmers are already using chemical fertilizers much more heavily, along with all the local manures and composts that can be secured. Nitrogenous fertilizers in particular are applied at an average of around 80 lbs. N/acre in those countries, and the rates are still going up. From the results of experiments done in China at different rates of application, I calculate that if nitrogenous fertilizers were used there on rice at 80 lbs./acre, along with phosphate and potash where needed at  $\frac{1}{2}$  cwt./acre, the direct effect of the fertilizers would be to increase yields by 46 per cent instead of the 36 per cent mentioned earlier. Adding 40 per cent for the effects of other technical developments, the combined effect of heavier fertilizer use and other improvements going on simultaneously would be to increase present rice yields by 86 per cent. This represents another 2,000 lbs./acre and would give an eventual average Chinese yield of 4,300 lbs. of paddy rice per acre.

As we shall see later, this figure is close to the average yield of rice in Japan today, which helps to confirm that the assumptions I have had to make are not too wide of the mark. Even this is not the end of the story, because with new varieties and improved water and disease control still heavier manuring will be practicable: but we have taken it far enough to show, from information already in hand, what could reasonably be expected in the not-too-distant future.

### (B) Dry-land Cereals

These include wheat, grown in the centre and north as a winter crop, and the summer grains—maize, millet and sorghum—which are important sources of food in western and northern China. There is not time to discuss them here in detail, but some conclusions follow based on calculations similar to those used for paddy rice.

*Wheat* yields and fertilizer responses are limited by the dryness as well as the coldness of the Chinese winter. In consequence, the average yield of unfertilized wheat in the experiments was low, being only 1,120 lbs./acre, and so was the direct response to fertilizers, which totalled 460 lbs./acre or 41 per cent. If, as with rice, we add another 40 per cent for the effects of the other improvements, the combined response to fertilizers and other developments likely to go on simultaneously would be 81 per cent, or an increase of  $\frac{4}{5}$  over current yields. The national average yield of wheat in China being 780 lbs./acre, fertilizers (at  $\frac{1}{2}$  cwt. of each plant food per acre) and other improvements would add a further 630 lbs./acre, giving a total improved yield of 1,400 lbs./acre. This is still low by the standards of intensive agriculture, but it is doubtful whether much more could be expected without irrigation. With irrigation—or a great extension of the area of wheat that is at present irrigated—dramatic further increases in Chinese wheat yields would become possible. This may be seen by comparison with what has been achieved in Mexico.

*Summer grains.* Being grown during the warm and wet summer monsoon, these—maize, millet and sorghum—give higher unfertilized yields and larger



responses to fertilizers than wheat does in China. In the Chinese field experiments the average response of the summer grains, excluding rice, to fertilizers was 755 lbs./acre, the average unfertilized yield being 1,800 lbs./acre: an average direct response to fertilizers of 42 per cent. This is similar to the corresponding figures for rice and wheat in China; by a parallel line of argument, we should expect the combined response to fertilizers and other developments to be about 82 per cent, where the fertilizers are used where needed at  $\frac{1}{2}$  cwt./acre each of nitrogen, phosphate and potash per acre. From yield-response curves, the combined response, if the rate of application of nitrogen was raised to 80 lbs./acre, would be very close to 100 per cent.

### Possibilities in India: (A) Rice

The results from a wide range of fertilizer trials and experiments, including many thousands of simple trials on cultivators fields, have been reported in recent years. Bringing together the information from various publications, I found an average response of rice to fertilizers in India of 590 lbs. of rough or paddy rice per acre: this is the combined effect of nitrogenous and phosphatic fertilizers, applied where needed, at 30 lbs. each of nitrogen and phosphate per acre. Figures for the average unfertilized yield in the trials are not available, but the over-all average yield of paddy rice in India—most of which is unfertilized—is 1,140 lbs./acre. On this basis the direct response to fertilizers is 52 per cent.

Because Indian farming is more primitive than that in China, and Indian soils are less fertile—local manures being little used—a larger allowance can be made

for the effects of other methods of agricultural improvements and their interactions with fertilizers. Cautious but reasonable estimates would be 20 per cent increase due to improved crop varieties, another 20 per cent for cultural methods, and 10 per cent for pest and disease control, the total being 50 per cent, instead of 40 per cent as in China. Adding this to the direct response to fertilizers, the combined effect of fertilizers and other developments proceeding simultaneously would be about 102 per cent: in other words, present rice yields would be doubled. The average improved yield of rice in India would then become 2,300 lbs. of rough or paddy rice per acre, which appears to be a realistic figure. It lies, for example, between the present average rice yields in Malaya (2,000 lbs./acre) and in Formosa (2,700 lbs./acre).

By modern standards the rates of application used in the Indian fertilizer trials were low ones: this was because (a) Indian farmers are unaccustomed to handling chemicals, and (b) the varieties of rice now grown in India cannot make use of much nitrogen. As the farmers gain experience and better rice varieties are produced, heavier rates of fertilizer use will become practical. From fertilizer response curves I estimate that 80 lbs. of nitrogen per acre, used on improved varieties along with phosphate and potash at  $\frac{1}{2}$  cwt. per acre where needed, would produce an average direct response of 1,040 lbs. of paddy rice per acre in India, or 91 per cent of the present average yield. Adding to this another 50 per cent for other agricultural improvements would give an over-all increase in yields of 140 per cent, with an average production of 2,700 lbs. of paddy rice per acre.



This is still a modest figure, comparable with the present average yield of rice in Formosa, but far below that in Japan, and with the further improvement and intensification of farming that is likely to occur in India under the stress of hunger, the process of increasing yields is not likely to stop there. We may well expect that average yields of 3,000 lbs. of paddy rice per acre or over will eventually be achieved in India, if not in this generation then in the next. There is certainly no climatic barrier as such to obtaining high rice yields in India. In officially observed competitions, Indian rice farmers have already produced yields on individual fields of from 8,400 to 11,200 lbs. of paddy rice per acre.

#### (B) Dry-land Cereals

*Wheat.* As in China, wheat is grown in India during the dry, cold winter, and this leads to low yields and limited responses to nitrogen. With irrigation rather better results are obtained: from the results of the field trials I estimate that the average direct response to fertilizers (at 30 lbs. each of N and  $P_2O_5$  per acre) by irrigated wheat in India was 430 lbs./acre, which would be about 45 per cent of the unfertilized yield. If, as with rice, we estimate a further 50 per cent for other improvements, the combined response to fertilizers, at the low rates used in the trials, and to other developments proceeding simultaneously, would be about 95 per cent.

Only one-fourth of the wheat in India is now irrigated, but irrigation is one of the major developments in the successive Indian Five-year Plans, and the proportion of wheat so treated will surely increase. Allowing for this and other improvements including greater

fertilizer use, we may conclude that the average yield of all wheat in India could readily be doubled, and that further increases would follow. As the present average wheat yield in India is only 660 lbs./acre, twice this figure at around 1,300 lbs./acre would still be a very modest yield by the standards of intensive agriculture. Having in mind what has already been done in Mexico, we might reasonably look forward to an eventual average yield of at least 2,000 lbs. of wheat per acre in India.

*Summer Grains.* These include, as in China, maize, millets and sorghum. Not much experimental work on these crops has been published in India, but I have seen the extremely poor, stunted and starved appearance of the crops themselves. There is no reason to doubt that what was found in China would hold good in India and that the present average yields of these crops could at least be doubled by the combined effects of fertilizers and other improvements.

#### Possibilities in Ghana: (A) Guinea Corn and Millet

These (Guinea corn is a sorghum) are the chief food crops in the Savannah belt of central and northern Ghana, as they are throughout this belt in West Africa. Large numbers of fertilizer experiments and simple trials have been carried out on both crops, and the average response of the two crops to low rates of fertilizer use (25 lbs. N and 22 lbs.  $P_2O_5$  per acre) was 486 lbs./acre. The average unfertilized yield was 714 lbs./acre, giving an increase of 68 per cent. Assuming, as for India, that the effects of other improvements would contribute another 50 per cent, then the combined response to



small applications of fertilizers and the other improvements would be about 120 per cent. The average yield level would be raised to 1,560 lbs./acre.

Further, as Ghana farmers gain experience and learn how to use heavier dressings of fertilizers, yields will become even greater: doubling the experimental rates, which would provide dressings that are still moderate by modern standards, would give a direct fertilizer response of about 100 per cent and along with other improvements a combined increase of 150 per cent over current yields. The average yield level would then approach 1,800 lbs./acre. Similar yield figures have already been obtained in actual manurial experiments elsewhere in West Africa.

The poverty of the ordinary cultivator's crops of Guinea corn and millet in West Africa has to be seen to be believed. When travelling through the country I have often observed, among these sparse crops, occasional fertile spots where the yield would be several times as great. They may have been old hut sites. Again, it is very noticeable how the crops become taller, greener and heavier near the farmhouse compounds, where the plants receive household and human waste products. These observations in themselves indicate what manuring could do to raise the production of West African food crops.

#### (B) Maize and Other Food Crops

These, including the tuber crops yams and cassava, are most important in the south of the country, in the woodland and forest belts. Here, fertilizer trials at rates similar to those mentioned under (A) have again given useful results, although there is no time to go into details.

The maize trials suffered from attacks of rust, and the low responses to fertilizers, namely 20-30 per cent, cannot be considered typical; cassava responded very well, with an average direct response of 77 per cent; yams, which as far as possible are planted on the more fertile soils, gave a 23 per cent response, so that the average response for both yams and cassava was 50 per cent. With heavier rates of application than the small ones employed in the trials there would, of course, have been much larger responses; and, as with the crops already discussed, an allowance should also be made for the influence of other improvements proceeding at the same time, although we hardly have enough information to put actual figures on these additional effects.

#### Possibilities in Mexico: (A) Wheat

Since the last war a well planned and intensive programme of agricultural development has been carried out in Mexico, through cooperation between the Rockefeller Foundation and the Mexican Ministry of Agriculture. Remarkable results have already been obtained, particularly with wheat. This is mainly grown as an irrigated winter crop in Mexico; most of the soils have been exhausted by continuous cropping and are low in available nitrogen, so that even with irrigation the average yield is low. Under these conditions there have been very large and widespread fertilizer responses, and heavy rates of application have proved profitable.

In an experiment in which various rates of nitrogen were combined with different levels of soil moisture, the best irrigation raised the yield only from 587

lbs. of wheat per acre to 612 lbs./acre where no fertilizer was used. Nitrogenous fertilizer at increasing rates produced continuously higher yields, reaching 2,154 lbs. of wheat per acre with the poorest irrigation and 3,990 lbs./acre with the best, when the fertilizer was used at a rate of 135 lbs. of N per acre. The increase with heavy nitrogen and better irrigation was thus 3,403 lbs. above the unimproved yield, a response of 580 per cent. The original yield was multiplied nearly seven times!

The figures well illustrate the type of interaction mentioned earlier, in which fertilizers become still more effective when other growth factors are also improved. Such heavy rates of nitrogen as these could only be used successfully because much research work had also been done to produce new wheat varieties resistant to lodging and disease.

Hundreds of field trials were carried out in the course of the research and development work in Mexico, but I do not have the results for comparison with those quoted for other countries. However, on most soils the fertilizer responses were comparable with those in the experiment just mentioned, even if rather less dramatic. Once the Mexican wheat farmers had been persuaded to try the new methods they adopted them enthusiastically, and it has been reported that some farmers are now harvesting 2,700 to 3,700 lbs. of wheat per acre on the same land that yielded only 370 to 620 lbs. per acre only four years earlier. In the course of achieving this, peasant farmers who had hardly seen chemical fertilizers before were soon applying dressings of up to 120 lbs. of nitrogen per acre— heavier applications, for wheat,

than those used even by sophisticated modern farmers in the U.S.A.

It required about ten years of experimental and development work and the gradual building up of a comprehensive farm advisory service before the peasants began to try the new methods; then they took to them rapidly. The effects of this can be seen in the average yields of wheat in Mexico, which were 732 lbs./acre in 1946; 767 lbs./acre in 1952; and 1,401 lbs./acre in 1958. In fact, by now the average yield of wheat in Mexico has almost been doubled, as a result of using fertilizers along with other improvements, and the experimental results suggest that the average yields could eventually be doubled again. At the least we can look forward with certainty to average wheat yields in Mexico three times those obtained before fertilizers and other improvements were introduced.

#### (B) Maize

Maize is the chief food grain in Mexico, and like wheat it has shown striking responses in fertilizer experiments, whilst many hundreds of demonstration trials have been done. So far the results in practice have been less striking than with wheat: this is partly because low rainfall or high altitudes limit maize yields and fertilizer effects in some regions of Mexico; partly because the maize growers in the more remote areas are more backward and slower to try new methods than are the wheat farmers. However, the yields of maize in Mexico are now beginning to increase: in 1946-7 the average maize yield was 660 lbs./acre, in 1957-8 it was 730 lbs./acre, and the estimate for 1959 is 760 lbs./acre. There is a large gap between



this and the present U.S.A. maize yield of 2,900 lbs./acre, and if Mexican maize growers could only half bridge the gap, the average yield would be around 1,800 lbs./acre. In view of what has already been achieved with wheat, this would seem to be a modest target.

#### WHAT FERTILIZERS HAVE DONE TO INCREASE CROP YIELDS

I could go on almost indefinitely giving examples based on field experiment results to show what fertilizers could do in other parts of the world, but the examples already given are widely representative of the less-developed countries, and they indicate that although the results vary with different regions and crops, yet large and progressive yield

increases can be achieved. In order to have an independent check on the assumptions I have made and the conclusions I have reached, I shall now examine what fertilizers, along with other scientific improvements, have actually done to raise yields in several countries that have modern, intensive types of agriculture.

**Wheat in England.** The average yields of wheat per acre in England or the United Kingdom since early mediaeval times are shown below. (Here and elsewhere, yields originally expressed as bushels per acre are transposed into pounds per acre for ease of comparison, because a bushel of wheat, for example, weighs much more than a bushel of paddy rice).

PERIOD (A.D.)	1250	1350	1550	1750	1850	1900	1950	1959
lbs./acre	380	500	940	1260	1640	1890	2350	3200

The low yields of the thirteenth and fourteenth centuries were those of the mediaeval open-field system, and are comparable with the yields obtained by the most primitive methods of shifting cultivation in under-developed countries today. By the sixteenth century there had already been some improvement in cultural methods, and perhaps more use was made of farm manure; the yields of wheat then being obtained in England were rather higher than the average wheat yields in India, Pakistan or mainland China in recent years. With the coming of the enclosures, better crop rotations and other improvements, yields continued to rise in England during the eighteenth and nineteenth centuries: the figure for 1850, of over 1,600 lbs./acre, represented what could be obtained by

good traditional farming methods including the use of farmyard manure, but practically no chemical fertilizers.

Since the mid-nineteenth century, with the gradual introduction of modern scientific methods including fertilizers, British wheat yields have continued to rise: in 1950 the yield was nearly 50 per cent above 1850, and in 1959 it was 95 per cent above 1850; in other words, the yields obtained by good traditional farming methods have almost been doubled. There can be no doubt that a large part of this increase, especially in recent years, has come from the increasingly heavy use of chemical fertilizers along with new varieties that resist lodging and disease. It would seem reasonable to attribute at least 50 per cent of the increase over 1850 yields to the direct

effect of fertilizers: responses of this order are still commonly observed in fertilizer experiments with cereals in Britain. English farmers have some way yet to go before they reach optimum levels of fertilizer use on cereals, so that the traditional yields of 1850 will be considerably more than doubled before the

process is finished. Even today, the yield of wheat in Britain is between 3 and 4 times what it was in Elizabethan England, and many times greater than in the early middle ages.

**Rice in Japan.** The average yields of paddy rice (rice in the husk) in Japan were as follows:-

PERIOD (A.D.)	8th Century	16th Century	1883-7	1898-1902	1918-1922	1938-1942	1948-1952	1959
lbs./acre	1130	1690	2190	2540	3200	3380	3570	4240

The story of rice yields in Japan is similar to that of wheat yields in England, except that throughout the period the yields of rice have been at a higher level in lbs. of grain per acre. This is partly because, unlike wheat, rice grown in flooded fields usually has an assured water supply; and partly because rice fields have their own sources of soil fertility, in mud brought in by the irrigation water and in nitrogen-fixing micro-organisms. The early mediaeval rice yield in Japan was similar to the average yield in India today.

It is striking to see that, as with wheat in England, the mediaeval rice yield in Japan was just about doubled by the 2nd half of the nineteenth century, as a result of improving the early cultural methods and using local manures. With the introduction of chemical fertilizers into Japan, along with scientific

improvements in cultural methods and in varieties, the increase in average yields continued, and by the present time rice yields have very nearly doubled again. As with wheat in England, so with rice in Japan it would be reasonable to assume that at least half of this doubling of the yields formerly obtained by traditional methods can be attributed to the direct response to fertilizers. Yet higher yields can be expected as a result of research work now in progress in Japan, combined with still heavier applications of fertilizers.

**Rice in Formosa (Taiwan).** In Formosa agricultural improvement began within living memory, so that we have almost under our eyes a picture of how a traditional type of Asian peasant agriculture can be developed by modern methods. The average yields of paddy rice were:

YEAR	1910-1	1920-1	1934-8	1946	1950-1	1959
lbs./acre	1555	1632	2195	1677	2168	2650

The rice yield in Formosa early in the present century, with traditional farming methods that included local manures, was similar to that in Japan

in the sixteenth century, and through technical improvements including fertilizer use it was raised by an average of about 40 per cent in the years before the



war. By the end of the war, as the result of an almost complete lack of fertilizers, the rice yield fell back nearly to where it had started from — which shows how great a part the fertilizers had played in securing the pre-war 40 per cent increase — and since then, with increased usage of chemical fertilizers and other improvements, the yield has been raised well above the pre-war levels. By 1959 the average rice yield per acre in Taiwan had been increased by almost three-fourths above the unimproved yield at the beginning of the century, and the extent of the wartime fall when fertilizers were lacking suggests that over half of this increase, or something approaching 50 per cent of the original unimproved yield, could be attributed to the direct response to fertilizers.

The average yield of rice in Formosa is still well below that in Japan, although fertilizer use is at least as heavy. This is probably because two or even three rice crops a year are grown in most parts of Formosa. Consequently, short-period varieties that do not have time to produce extremely heavy yields are used. If we take the output of rice per acre per year, instead of per crop, then Formosa is already ahead of Japan: on double-cropped land, the annual output would average some 5,300 lbs. per acre as against 4,300 in Japan.

### Discussion

In spite of the variability of the results with different crops and countries, it is fair to say that on the whole the direct response to chemical fertilizers, used at low to moderate rates in less-developed countries, varies around 50 per cent of the unfertilized yield; and

that the combined response to fertilizers and other methods of improvement going on simultaneously averages around 100 per cent. In other words, the present production of food crops in the less-developed countries could be doubled by using moderate fertilizer treatments and other techniques that could be put into effect without delay.

How much further the improvement in yields could go depends on such matters as the present fertility of a country's soils, and whether or not irrigation is available in dry climates. On the more fertile soils, such as those in China, where crop yields are already moderately high, doubling the original yields would be about the limit that could reasonably be expected from the techniques now available. On the less fertile soils, such as those in India and Tropical Africa and America, the full application of modern intensive methods, including heavier fertilizer dressings and suitable new varieties, could not only double the original yields but double them again in many places, or at least add another 50 per cent. Thus in the long run the production of food crops from the present areas could even be multiplied three or four times. Extension of the crop areas, or of the irrigated areas, would still further enlarge the capabilities of using fertilizers: irrigation, in particular, along with other agricultural improvements, makes possible remarkable responses to heavy fertilizer dressings.

These broad conclusions are confirmed by what has actually been done in countries like England and Japan, where the low mediaeval yields of food crops were approximately doubled by im-

proving the farming methods along the traditional lines, including local manures, and then doubled again by introducing the techniques of modern intensive agriculture. I estimate that about 50 per cent of this last increase could be attributed to the direct effects of chemical fertilizers.

Another pointer leading to the same general conclusion has been stressed by Dr. H. Greene of Rothamsted: namely that in under-developed countries the maximum yields obtained in fertilizer experiments at agricultural research stations are often three or four times the yields that the peasant cultivators around the station are getting.

### **Current Food Production Could be Multiplied Several-fold.**

The experimental results given earlier, and the ensuing discussion, have all related to the principal food crops, and it is reasonable to assume that food production as a whole in most of the less-developed countries—the ones with the severest population problems—could be doubled and eventually trebled or quadrupled by using fertilizers and other modern agricultural methods.

The speed with which this can be done is very much a matter for the countries themselves. Although more field experimental work will be needed in individual countries to ensure that fertilizers are used with full efficiency, and numerous field trials will be wanted for demonstration purposes, we know enough to make a start. Additional experimental work, varietal improvement and so forth can be proceeding while the agricultural development is going on. The limitations to rapid increases in home food

production are social, financial and educational rather than technical. In particular, the less-developed countries will have greatly to increase their farm advisory or extension services. One advisory officer in the field to every thousand farmers is not enough in the under-developed countries.

If the government of a less-developed country regarded the food problem as grave enough to justify such an expenditure of money and effort as would really get results, then food production could be doubled within a generation, which would take care of any conceivable rate of population increase. The process would not stop there, however: in the course of time food production could be doubled again; and by then, either better control of population increase or new scientific developments in food production would be influencing the picture.

I have said nothing about grasslands and the production of animal foods. This was not because I do not think them important—they are immensely so—but the subject is so complex that there is simply not time to do justice to it. Just as examples of what fertilizers can do, I would mention the improvement of pastures by superphosphate in Australia and New Zealand—which has increased output many-fold—and the grassland management investigations of I.C.I. Ltd., in Britain, which have shown how profits as well as production can be raised by the skilful use of fertilizer, particularly nitrogen, and good management.

In this paper I have focussed attention on what can be done in the under-developed countries, because they are the ones where food and population problems are most serious. There is not time to



discuss also the more highly developed countries with their intensive agriculture, but even in many of them fertilizers and associated improvements could further increase food production. Britain, for example, has increased her agricultural output by 60 per cent since before the war, and fertilizer use has been multiplied several times in doing so, yet the possibilities of further crop increase are not exhausted. In the U.S.A., with important crops like wheat and maize, although their average yields have risen since pre-war the process of increasing them still has far to go. If there were no crop surpluses, the current U.S. yields of these crops could at least be doubled by using more intensive modern methods, including heavier fertilizer dressings. To increase food production further in countries that already have a highly intensive agriculture will be the most difficult problem, yet even here there are possibilities that are now being explored in agricultural research.

**Why Not Top Yields?** I have shown the increases in food production that the world can expect from applying the knowledge we already have and the techniques generally used in modern intensive agriculture. There are still greater long-term possibilities that may be revealed by investigating how it is that the average crop yields obtainable by good intensive methods are so far below the "top yields" given by certain favoured fields.

Crop competitions and officially observed measurements in many countries —

even the less developed ones — have recorded yields from individual fields ranging from about 8,000 to over 12,000 lbs. of food grain per acre; say, around 5 tons an acre. By contrast, even the highest national average yields for food grains are between  $1\frac{1}{2}$  and  $2\frac{1}{2}$  tons an acre. We can guess at some of the reasons that make the favoured fields so fertile, but we do not fully know. If we really knew the explanation, then given the power of the scientific method and modern technology, it should eventually be possible to produce such yields to order on a large part of the cultivated land.

Intensive investigations into the why and wherefore of these high yields, or what prevents their general attainment, have already begun in countries such as Japan where the population and food problems are most pressing. If as much money and scientific effort was devoted to the problems of world food supplies as that spent, for instance, on atomic energy, rocket research and space travel, the answers would soon be found. Perhaps this stage will be reached by the turn of the Century, if the "population explosion" has not been brought under control. By then fertilizers may be reckoned as important as steel, for example, and required in similar quantities. When we know how to secure top yields more widely, we shall be able to look forward with confidence to producing very many times the present quantities of food in world, and in this chemical fertilizers will continue to play a major part.

## RICE IN THAILAND

Sala Dasananda<sup>1</sup>

## Rice Production Statistics

The total land area of Thailand is 51.4 million ha. of which nearly 19% is cultivated. Rice is grown on 6.012 million ha. constituting 62.5% of the cultivated area. A second crop of rice is raised in only a very small part of this area amounting to about 11,270 ha.

The total irrigated area in 1950 was only about 0.88 million ha. By 1955 it

had increased to 1.1 million ha. and the irrigation projects now in progress are expected to bring the total irrigated area to 1.76 million ha.

The production of paddy during 1956 amounted to 8.296 million tons – a record production for the country so far. The area, production and yield in the four broad geographical regions were as follows:

	<u>Area</u>	<u>Total Production</u>	<u>Yield</u>
	Million ha.	Million Tons	kg. per ha.
Central region	2.71	4.22	1557
North-East region	2.48	2.62	1056
Northern region	0.37	0.79	2135
Southern region	0.45	0.66	1466
Total	<u>6.01</u>	<u>8.29</u>	<u>1380</u>

The production per capita for the population of 22.811 million was about 363 kg. There was a surplus of 3.063 million tons of paddy and during the year the exports of milled rice and rice products amounted to 1.272 million tons. In 1957 the export figures were 1.557

million tons which obviously included a carry-over from 1956.

Most of the surplus is from the central region which is, therefore, important for the production of rice for export. The surpluses in the different regions are given below in percentages of the total surplus:

	<u>Surplus Paddy</u>	
	<u>Million tons</u>	<u>Percentage</u>
Central region	1.965	64.2
North-East region	0.831	27.1
Northern region	0.227	7.4
Southern region	0.040	1.3
Total	<u>3.063</u>	<u>100.00</u>

<sup>1</sup> Deputy Director-General, Rice Department, Ministry of Agriculture, Bangkok, Thailand.



## The Rice Department and Its Organization

All work connected with the development of rice cultivation and rice research is organized by the Rice Department established in 1954.

In addition to administration, there are four divisions in the Rice Department: (a) breeding, (b) technical, (c) engineering, (d) extension.

**(a) Breeding Division.** Dr. Sala Dasananda is Acting Chief of this Division. At the present this Division is responsible for the breeding work and foundation seed multiplication and supervision of all stations and the regional tests.

**(b) Technical Division** under Dr. Bhakdi Lusananda deals with various researches on agronomy, physiology, pest, diseases and soil fertility, including soil survey and seed testing work.

Work has been initiated in the testing of varieties for sensitivity to photo-periodism, testing varieties for blast resistance, studying the methods to overcome dormancy in rice seed, water requirement. This division is also in charge of the soil survey and the soil analysis laboratory, and the various fertilizer experiments in progress at the experimental stations and on farmers' fields.

**(c) Engineering Division** under the leadership of M.R. Debriddhi Devakul, offers ploughing and threshing services on a limited scale to the farmers for nominal fees in the central region.

This division is also responsible for improvement of small farm tools. A small tractor "Iron Buffalo" was designed and developed by the Engineering Division and is now under production for sale to the farmers. This "Iron Buffalo" powered by an eight horse-power diesel engine, not only serves as a suitable tractor for the wet muddy rice fields but also as an economic source of power for versatile operations such as pumping, threshing, etc. on the farms.

**(d) Extension Division** under Mr. Sawasdi Cheosakul controls the activities of the Rice Extension agents numbering about 250 all over the Kingdom. Its main tasks at the present time are to carry out the seed multiplication program in the villages, the large scale pest control work—a free service offered by the government to the Thai rice farmers—to stimulate the use of fertilizer and to sell and distribute it to farmers, and to carry out extension services and to advise on the rotation of crops and diversification, and balanced farming. Recently encouragement has been given to the organization of farmers' associations for the mutual benefit of farmers.

## Rice Cultivation

Rice is mainly transplanted and the area sown by broadcasting is only 20.5 % of the total area under rice. Considering the different geographical regions, however, the proportions vary widely as shown below :

	Broadcast	Transplants
	%	%
Central region	41.7	58.3
North-East region	0.9	99.3
North region	1.0	99.0
South region	17.3	80.7
Average	20.5	79.5

In the area in the central plain where broadcasting is the normal procedure, 75% is sown with floating rice. With the completion of irrigation works under the Chainat dam and the Phumipol dam, this deep water area is expected to shrink considerably.

Another characteristic feature of rice culture in Thailand is the growing of glutinous varieties of rice mostly in North and North East regions for local consumption. The percentage of the area grown with ordinary and glutinous rice indicates the regional importance of the respective types.

	1956	
	Non-glutinous	Glutinous
	%	%
Central region	96.3	3.7
North-East region	26.3	73.7
North region	8.0	92.0
South region	93.7	6.3
Average	61.8	38.2

The special features of rice cultivation in Thailand are (1) the growing of rice as a broadcast crop in nearly 40% of the rice area in the Central Plain, which is the rice bowl of Thailand, contributing 64% of the export, (2) the importance of glutinous rice in North and North East regions and (3) floating rice.

Cultivation in the Central Plain as compared to the Northern region (Chieng-mai area) is not intensive and very little attention is being given to weeding especially in the 'broadcast' areas which include all floating rice. In the 'transplant' areas a seed rate of 50 kgs. per ha. is the general practice though it may be more, and in the 'broadcast' areas the seed rate used is 100 kgs. per ha. In both cases the seed rate could profitably be reduced by about 40%. This would result in better yield and the saving of seed would amount to not less than 150,000 tons of paddy and would thus add 97,000 tons of polished rice to the exportable surplus equivalent to about 8% of the present export.

In this connection, it may be mentioned that attention should be given to experiments on the agronomic aspects of rice cultivation, with special emphasis on well known practices of low seed rate, lay-out of the nurseries, transplanting in lines, drilling instead of broadcasting and weeding practices by the use of rotary weeder, etc.

### Breeding

Though the Rangsit experimental station was established in 1916, real large-scale scientific breeding work was only initiated in 1950 with the help of technical aid from the U.S.A. and the able guidance of Professor H.H. Love of Cornell University, and in January 1954 the Ministry of Agriculture established a separate Department of Rice with M.C. Chakrabandhu as Director-General.

The program of work is conducted in three phases, i.e. variety evaluation, selection and hybridization. The first two phases were taken up at the same time. The standard varieties established



by the Government, varieties selected from different parts of the country and samples of prize-winning varieties were tested at the different experimental stations and were then followed by regional trials on the farmers fields in various parts of the Kingdom.

Simultaneously head selections from varieties grown by the farmers in different localities were also taken up on a large scale. The first collection numbered 120,000 panicles. A subsequent collection of panicles was made about every 2 or 3 years numbering from 20,000-60,000 panicles in each collection, and at the present time there are more than 45,000 lines under various stages of selection at all the experimental stations. This comprehensive program was made possible by the training of suitable personnel through short courses on selection method and field experimentation. With the establishment of the Rice Department new recruits of University graduates and vocational high school graduates have helped the expansion of the program, especially in increasing the number of experimental stations from seven to fifteen.

Listed below are rice experimental and seed stations:

<u>Region</u>	<u>Rice Station</u>
1. North	San Patong Pahn

2. North East	Pimai Surin Chumpae
3. Central Plain	Rangsit Bangkhen Kok Samrong Chainat Nakornpatom Rajburi Klong Luang Huntra (Floating rice station)
4. South	Kuan Gud Nakornsriathamraj.

These experimental stations vary somewhat as to the amount of work load. All of them are engaged on variety testing and seed multiplication for the nearby districts. Other experiments on soil fertility, agronomy, crop diversification and rotation, pest and disease control are also undertaken. Recently, a coordinated program of testing for blast resistance has started at all stations. These stations also act as regional seed laboratories to check stock seed quality.

In 1956 thirteen varieties were recommended for the North, the North East and the Central Plain regions of Thailand. In 1959 at the second meeting of the varietal committee some varieties were withdrawn and some new ones added. The following varieties are now recommended:—

Recommended Rice Varieties<sup>1</sup>

Name	Type		Regional Adaptation		
	Starchy	Glutinous	North	North East	Central
1. Khao Dawk Mali 105	x			x	
2. Nahng Mon S-4	x			x	x
3. Muey Nawng 62		x	x		
4. Daw Nahng Nuan 91		x		x	
5. Leuang Yai 34	x		x	x	
6. Nahng Chalong (Floating)		x			x
7. Pah Leud 111		x	x		
8. Tapow Gaew 161 (Semi-floating)	x				x
9. Jek Chuey 159 (Semi-floating)	x				x
10. Leuang Awn 29	x			x	x
11. Leuang Rahaeng 8	x			x	x
12. Khao Tahaeng 17	x			x	x
13. Leb Meu Nahng 111 (Floating)	x				x
14. Puang Nahk 16	x				x
15. Pin Gaew 56 (Floating)	x				x

Work is now being continued at the different stations with a more extensive and exhaustive collection of local varieties and their evaluation, along with the testing of new lines obtained from head selections. Regional tests are now underway in 130 localities, 60 in the Central Plain, 20 in the North, 35 in the North East and 15 in the South. In each of these regions twenty new promising varieties, including selections, are being tested, along with one or two standard and three or four local varieties, for three years in randomized block with six replications.

The hybridization program during 1950-54 was confined to the FAO Indica-Japonica hybridization project and recently work has been extended to hybridization between promising local varieties to introduce mainly non-lodging habit, high yield and high quality of grain.

The rigid demand of the rice trade in Thailand for high quality long grain rice allows very little flexibility for the breeder in making a selection of non-glutinous rice, while in glutinous varieties two types of grain are predominant, one broad and round for the Northern area and the other slender and longer for the North East region.

During the past two years, due to increasing damage by *Piricularia oryzae*, an intensive breeding program for blast resistance was initiated with the assistance of an FAO expert.

The future aims in the hybridization program will include breeding of early maturing, low-photosensitive varieties with high fertilizer response.

## Floating Rice (Deep-water rice)

Work on the breeding of improved varieties is in progress at the Huntra

<sup>1</sup> The varieties have been placed in the order of maturity, the earliest No. 1 flowering by the middle of October, while the latest, No. 14 & 15 flower by the last week of November.



deep water station. Though in general cultivation the seed is sown broadcast, breeding material is sown in nurseries and transplanted at regular spacing of 25 x 25 cms. between hills.

A square plot 2 meter x 2 meter is employed instead of the usual 4.5 meter 3-row plot. A space of 1 meter is kept between the plots in order to avoid the varieties growing adjacent to each other getting entangled. According to the withdrawal of the water in the area subjected to flooding, these floating rice varieties are grouped roughly into three groups, (1) early, harvested last week of November or early December, (2) medium, harvested around the middle of December, (3) late, grown in the deeper areas and harvested the last week of December or January.

For the improvement of floating rice, a detailed morphological study of the variations present in this type of rice has to be made. Special emphasis is given to tillering, branching at nodes, the size of heads on the main tiller and branches, and rooting at the different nodes. Selection work has resulted in the improvement of grain quality and yield equal to that of the ordinary transplanted rice. As weeds are prevalent throughout the area, it will be necessary from the agronomic aspect to investigate the practice of drilling or dibbling of seed in plough furrows and inter-culturing until the crop gets flooded.

### Use of Irradiation in Breeding

Seed samples of two rice varieties were exposed to X-rays and to thermal neutrons at the Brook Haven National Laboratory. The X5 and R5 generations are now grown at both Bangkhen and Rangsit stations. Mutations for earliness and other useful agronomic characters have been isolated while mutations of no economic value have been discarded. Plans

have been made to test these progenies for blast resistance and to include some of the promising lines in yield trials during the coming year.

### Breeding for Disease Resistance

It is found that foot rot (*Gibberella fujikuroi*) is fairly prevalent in the Northern region and special attention has to be paid to the breeding of varieties resistant to this disease. At present the campaign on seed dressing is being carried out by the Extension Division of the Rice Department in this region.

Blast (*Piricularia oryzae*) has become important in recent years imposing a big responsibility on the breeders. The FAO Rice Disease Specialist, Dr. S.H. Ou, is helping in planning a program of work and in developing proper techniques on blast study and testing. Work has progressed very satisfactorily during the past year and a sound breeding program for blast resistance is now in progress.

### Seed Multiplication and Distribution

On the establishment of the Rice Department, a seed program was started with two committees at top level: one, the Rice Seed Coordinating Committee to decide on the policy, objectives and working plans regarding seed education, seed production and certification and distribution, and the second, the Variety Committee to decide on the varieties for distribution or withdrawal. These committees include members from the Rice Millers Association and merchants' and farmers' representatives in addition to members of the Rice Department and Ministry of Economic Affairs.

Seed Committees are being organized at the village, district and province levels. Rice agents, about 250 in number, are promoting the organization of the village committees with the help of district officers and meetings with the elders of the

villages. Each village committee consists of five members: chairman, secretary, seed inspector and two others. These committees help in the selection of village seed growers, and already 11,000 village committees with 25,000 stock seed growers have been organized. Foundation seed is supplied by the experimental stations. The supply for each seed grower is a cloth bag containing 5 kgs. of foundation seed sealed with the emblem of the Rice Department. The cost is about 25 cent U.S. per bag and one bag is sufficient to plant one rai (1/6.25 ha.). Rice inspectors are trained to inspect the crop and send samples of seed soon after harvest for testing at the experimental stations. In this connection the seed laboratory of the Technical Division, Bangkok is interested in finding a quick method of breaking the dormancy for the necessary germination test and expedite the seed certification. It is estimated that nearly  $\frac{1}{2}$  million tons of paddy will be the annual requirement of improved seed inclusive of broadcast areas for the whole kingdom. The seed produced by the stock seed growers will be enough to cover nearly 1/30th of the rice area and one further multiplication will give sufficient seed to meet the total requirement.

To obtain good results it is necessary that a sound seed program is developed in each individual village. A recent survey has shown that many of the village seed committees have been inactive. The success of the program will depend on the efforts of the rice agents. At the present time, however, these are few in number compared to the magnitude of the program and therefore a further increase is necessary to make the seed program effective.

## Fertilizer Experiments

The increase in production in recent years has been due to an increase in acreage. The average yield per hectare has, however, been more or less steady during the past thirty years. Experiments on the effect of various chemical fertilizers have been conducted for a number of years at various stations. More than 100 experiments are also being conducted each year in the farmers' fields to determine the effect of different kinds and amounts of fertilizers under different soil-management conditions and the levels of fertilizers to be used by the farmers to obtain economic returns.

Responses to nitrogen and phosphates are almost universal and a combination of N and P gives very good yields. Responses to potassium are however confined to mainly the Northeastern region. Lime, in some instances, gives marked response when accompanied by phosphate in highly acid soils.

The effects of various green manures and rotational crops on soil fertility have also been under investigation at 4 experimental stations. It was definitely shown that green manures and some rotation crops can improve the fertility of the rice soil especially in the North East region.

## General

During the seven years since it was established, the Rice Department has made great progress in its organization. Experimental stations have been equipped and staffed for carrying out research programs and for maintaining pure stock of foundation seed. Through research basic information has been obtained on how to increase the yield per unit area but the extension phase of the overall program is still lagging behind. It is still felt that there is room for improvement on the research side. This also applies to the training and recruitment of personnel.



## THE CULTIVATION OF UPLAND RICE IN ROTATION WITH GROUNDNUT IN SENEGAL

C. Magne<sup>1</sup>

### Origin

In Senegal, rice is cultivated mainly in the province of Casamance. It is either transplanted on flooded land or directly sown on high land. The yield per hectare is on the average 1,200 kgs. in the former and 800 kgs. in the latter. In the Sédhiou region, the crop is cultivated exclusively by women in fields which are their property.

It is in this region that a semi-governmental company, the "Compagnie Générale des Oléagineux Tropicaux" (CGOT) with a major share of public capital, was given in 1948 the responsibility for clearing various tracts of land and undertaking the mechanized cultivation of groundnuts. The insufficiency of edible fats and oil which prevailed during the post-war period was the reason for this project. This cultivation, which was first done experimentally on 1,600 ha., was unprofitable due to small yields—1,200 kg/ha—while to ensure a profit it would have been necessary to get 2,000 kg/ha.

This failure led the CGOT to investigate, with the help of the Séfa Experiment Station situated in its area, the possibility of growing suitable crops in rotation which could ensure at the same time the maintenance of soil fertility and

the economic advantage from the undertaking.

Upland rice cultivation was tried with success; in rotation with groundnut, it was found to be as good as millet. Rice cultivation could also be easily mechanized, and contrary to a widely held opinion, it was found to cause less soil erosion than other crops.

Beside the introduction of rice in the cropping pattern, the CGOT also modified its farming system by seeking the cooperation of the African farmers in particular farming operations. While the CGOT took charge of all the mechanized cultivation with regards to rice and also the preparatory tillage with regards to other crops, the rest of the operations such as sowing, weeding and harvesting of groundnut and millet were done by the farmers.

### Crop Rotation and the CGOT's System of Association with Farmers

The following cropping pattern is adopted for most lands:

- 1st year — green manure (Sorghum)
- 2nd „ — groundnut
- 3rd „ — rice or millet
- 4th „ — groundnut

The following table shows the distribution of crops, operations and production, for an average family-size plot of 6 ha.

Crop	Ha.	Operations		Average Production kgs.	Share	
		CGOT	Farmers		CGOT	Farmers
Groundnut	3	tillage	{ Sowing Maintenance Harvest	4500 400 1200	{ fixed 1500 kgs. groundnut	3000 400 —
Millet	0.5	tillage				
Rice	1	all				
Green manure	1.5	all	—	—	—	—

<sup>1</sup> Geneticist, C.G.O.T. Experiment Station, Ziguinchor, Senegal, West Africa.

A fixed share of 1500 kgs. of groundnut is claimed by the CGOT in return for the services rendered to the farmer, i.e. tillage, green manure cultivation, rotation, social services and transportation. The profit from marketing of the produce also belongs to the CGOT.

## The CGOT's Rice Cultivation

### a) Natural Environment

The climate in Casamance is of the Guinean type with a rainy season from June to October. The annual rainfall ranges from 900 mm. to 1,700 mm. with an average of 1,300 mm., of which 450 mm. falls during the month of August alone. The intensity of the rainfall favours erosion. The irregularity of the rains at the beginning or end of the season is often detrimental to rice yields because of poor germination or drought damage.

The CGOT's farms are situated on a plateau, the soil of which is of the ferruginous type: red or brownish-yellow, composed of 80% sand and 8% clay. Due to the danger of erosion, only the areas where slopes are less than 1.5% have been cleared.

### b) Preparation of Land and Sowing

For tillage, 16-disc ploughs drawn by TD 9 tractors have been used. Tillage starts after the first rains, as soon as the weeds begin to sprout. Tillage depth is 8 to 12 cm.

Sowing is started with the commencement of the regular rains about July 1st and finished by July 12th. It is preceded by one harrowing or one light ploughing by cultivator. Drills are used with 20 cm. spacing.

Since tillage and sowing both for rice as well as for groundnut has to be

completed in less than 25 days, it is found necessary to work the machines day and night.

### c) Varieties

The CGOT cultivates at present 2 varieties of medium grain rice: 560 A—a selection from a Madagascar variety which has a maturity period of 115 days and has to be sown before 7th July and R67—a selection originating from Yangambi (Congo), having a 105-day maturity period which is sown between 7th-12th July.

These two varieties are not sensitive to photoperiodism and resist lodging quite well. Selection work has been undertaken in order to obtain a variety which will be a little earlier than 560 A and more resistant to *Piricularia oryzae*.

### d) Fertilizers

The Séfa Research Station recommends for rice the following applications (doses per hectare):

Before sowing—50 kgs. of dicalcium phosphate  
70 kgs. of potassium chloride

Top dressing —150 to 200 kgs. ammonium sulphate in two applications.

Except for the last application of ammonium sulphate which is done by hand, all fertilizers are spread by mechanical distributors.

In addition, for the rotational crops 500 kg/ha of tricalcium phosphate is applied for green manure immediately after clearing and 75 kg/ha of dicalcium phosphate and 75 kg/ha of potassium chloride for groundnut.



Until 1959, such high doses had never been applied, which partly accounted for the low yield of 1,200 kg/ha obtained until then. In 1960, when the recommended doses are going to be applied, more than 1,500 kgs. of yield of rice per hectare are expected.

### e) Weed Control

Rice would be quickly overrun with weeds if these were not mechanically or manually removed.

Grasses of the following genera are found everywhere:

Pennisetum  
Digitaria  
Eleusine  
Panicum  
Paspalum

Tillage and ploughing destroy the weeds sprouting before the sowing of rice. Those that grow afterwards are easily removed by rotary hoes after a short dry spell. Later, all weedings are done by hand. The average amount of hand labour for weeding is 130 man-hours per hectare.

### Diseases and Pests

Variety 560 A has sometimes been affected by *Piricularia* which causes serious damage. Grain-blight caused by *Helminthosporium* and *Curvalaria*, affects both varieties. The seeds are treated regularly with an organic mercury compound. Polyphagous insects such as *Zonoceros variegatus* and *Laphygma exempta* have caused serious damage in certain years. *Leptocoriza apicalis* has also caused loss both in rice as well as sorghum.

### Harvest

Harvest is carried out with self-propelled combined harvesters. Begun at

the end of October, it lasts 3 weeks to 1 month. Each machine harvests 0.75 ha/hour on the average. After winnowing, rice is stored in bulk in bins equipped with a ventilation system.

### Production and Yield

In 1958, a year which can be considered average, the CGOT cultivated 774 ha. and harvested 929 tons, the approximate average yield being 1,200 kg/ha. In fact, the yields fluctuated between 1,000 kg/ha. and 1,700 kg/ha. in the previous years. It is hoped that with the recommended doses of fertilizer application, average yields will exceed 1,500 kg/ha.

### Processing

All harvested paddy is processed by the CGOT rice mill. Sixty six to sixty eight percent of white rice is obtained, half of which is head rice. All the produce is marketed within the region.

### Cost Price

The cost price per hectare of various cultivation operations for 1958 is given below in CFA<sup>1</sup> francs:

Tillage (TD 14 and 16 disced plough)	1171
Hoeing	799
Fertilizers and cost of application	5304
Seeds	1643
Sowing	1069
Weedings	6401
Combined harvester	5359
Transportation, winnowing, storage	784
Green manure	4500
Overhead expenses 15%	3400
	<u>30560</u>

<sup>1</sup> US\$1 = 245 CFA francs

The price of paddy being about 20 fr/kg., these expenses would be covered by obtaining a yield of 1,500 to 1,600 kgs. As an average yield of only 1,200 kgs. has so far been obtained, the company has been working at a loss as far as rice is concerned.

### The CGOT's Mission and the Problem of Profit

In view of the chronic deficit in mechanical rice cultivation, it has been contemplated to grow rice in association with the farmers as has been done already in the case of groundnuts, or even to replace rice entirely by millet. Unfortunately, the low price of food grains makes their cultivation less remunerative than groundnut. This solution would result in considerable losses for the associated farmers. The aim of the CGOT, being a State Company, needs not necessarily be lucrative. Its mission is to contribute to the economic development of the country and also to ensure for its associates a standard of living higher than what they would have had under the traditional agricultural system. However, it hopes to wipe out the deficit and secure profits by developing processing and marketing activities and also by making use of the results of researches in progress in connection with improvement of varieties as well as in the use of fertilizers. The achievement of this objective will

give CGOT greater financial freedom and will possibly enable the company to consider new expansions.

### Summary

The Compagnie Générale des Oléagineux Tropicaux (CGOT) cultivates upland rice in Senegal in the following rotation: green manure – groundnut – rice – groundnut.

This rotation is carried out with the participation of farmers who take charge of the sowing, maintenance and harvest of groundnuts by traditional means. The CGOT takes care of the ploughing and all cultivation operations of rice and green manure, by mechanical means.

Rice yields have been 1,200 kg/ha. on the average until now. Irregularity of rainfall at the beginning and the end of the rainy season, growth of weeds and diseases, are the main factors limiting the yields. It is hoped to reach an average yield of 1,500 kg/ha. by higher applications of fertilizers. Selection work is being undertaken to obtain earlier and disease resistant varieties.

Until now, it has been difficult to obtain a profit out of rice cultivation. The CGOT has kept this crop in view of a cropping pattern which has so far allowed a continuous cultivation without soil depletion, and ensured a high income for the associated farmers, as a result of groundnut cultivation.



## PLANS FOR COOPERATIVE VARIETY TESTING OF IMPROVED RICE VARIETIES WITH WIDE ADAPTATION

At the Eighth Meeting of the IRC Working Party on Rice Production and Protection held in Ceylon in December 1959, a summary report was given on the cooperative variety trials conducted in participating countries since 1956. The results obtained in these trials indicated that although in most cases varieties introduced from other countries had been inferior to the best indigenous ones, introduced varieties had, in some cases, given very promising results. Very good performances have been shown by Norin 29 from Japan and Caloro from the U.S.A. in Korea, Pebifun from Taiwan in the U.S.A., Norin 6 and Tsurugiba from Japan in Egypt. In the same way some Indian varieties have given good results in Burma, Malaya and Indonesia and in various states of India varieties from Ceylon, Burma, Indonesia, the Philippines and Japan have given promising results.

In most rice growing countries and especially in those with an advanced breeding program, more and more attention is now being given to the development of varieties in which high yield capacity, straw stiffness, disease resistance, good fertilizer response and other valuable characters are combined with wide adaptability. In some countries such varieties have already been developed and distributed to the farmer and some of them are grown over large areas with different environmental conditions. Other new promising varieties are under final tests. It is obvious that such widely adapted varieties could be of great value also in other countries, primarily in areas where the ecological condi-

tions are rather similar to those in the country of origin, but possibly also in countries with rather different ecological conditions. It was felt by the Working Party that it would be of mutual interest to all countries if such varieties could be tested as widely as possible outside the country of origin. It was, therefore, recommended that the old project on cooperative variety trials should be discontinued and replaced by a new project. The objective of this project should be to test as widely as possible such new varieties which have already shown wide adaptability in their countries of origin in order to find out if any of these would be of value in other countries, either for direct practical work or as breeding material.

The scheme should be conducted as follows:-

1. Each country provides FAO with a list of some very good rice varieties available in the country and from which seed can be made available for experiments in other countries. The varieties listed shall have good overall characteristics and have shown high adaptability under different ecological conditions and good performance over wide areas. A short description of each variety should be attached including the origin of the variety, general type, maturity group, size and type of grain, straw length and straw-stiffness and, if possible, information concerning photosensitivity, response to fertilizers, resistance to various diseases and other important characters. An indication should also be given on the extent to which the wide adaptability

characteristic has been established and in what way.

2. FAO compiles a list of varieties on the basis of the information obtained from various countries and circulates it to all IRC member countries.

3. Countries interested in testing any of the listed varieties request through FAO the seed of the varieties they require and FAO arranges for this seed to be distributed.

4. The experiments will be conducted under good farming conditions and at medium to high fertility level. The introduced varieties should be compared with the best local standard varieties in these experiments. All observations and results should be reported to FAO as soon as they are available.

5. FAO compiles once a year a report on the results obtained and distributes this report to IRC member countries.

6. When a new variety with good characters and wide adaptability has been produced it should be reported to FAO for inclusion in the list of varieties circulated to the member countries. In that way new outstanding varieties developed in any of the member countries will be known and made available for testing in other countries without delay.

7. Dr. N. Parthasarathy, Rice Improvement Specialist, FAO Regional Office for Asia and the Far East, Maliwan Mansion, Phra Atit Road, Bangkok, Thailand, will act as coordinator for these trials and all related correspondence should be directed to him.

In order to get the project started in the 1961 season, cooperators in all countries are asked to send in the information concerning suitable varieties as soon as possible. Detailed instructions concerning the conducting of the experiments will be sent later.



### **Announcement**

Dr. V.P. Rao, Director of the Commonwealth Institute of Biological Control, Indian Station, Post Box No. 1503, Bangalore (6), India, has requested the International Rice Commission to announce in its quarterly newsletter that the Institute has taken up the study of Oriental Neuropterous insects, particularly those belonging to the families Chrysopidae and Hemerobiidae on account of their predacious habits and use in biological control. Dr. Rao would very much appreciate this Commission to circulate this information to all the member countries in the orient so that Entomologists and others interested would kindly send to the abovementioned address both identified and unidentified specimens to him for study and review. Identified specimens would be returned as soon as done with. He would very much appreciate any assistance that could be given in this matter and would be grateful to acknowledge this assistance.

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## NEWS LETTER

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### TABLE OF CONTENTS, 1958-60

#### Volume VII, No. 1 — March 1958

1. Rotational irrigation for rice—a revolution in Taiwan, by Lee Chow.
2. Effects of water depth on the growth and yield of lowland rice, by Julian Bulanadi and Primo B. Aldaba.
3. Lime as a remedy for a physiological disease of rice associated with excess iron, by F.N. Ponnamperuma.
4. Time and methods of application of urea, a Contribution from Japan.
5. Impressions of agricultural extension work in the United States of America, by C.W. Chang.
6. Review of "Rice in India", by N. Parthasarathy.

#### Volume VII, No. 2 — June 1958

7. Agricultural extension in Asia, by C.W. Chang.
8. Paddy soils, by R. Dudal.

9. Natural cross-pollination in rice in Malaya, by F.B. Brown.
10. The Sixth Session of the International Rice Commission.

#### Volume VII, No. 3—September 1958

11. The Hoja Blanca disease of rice, by John G. Atkins and Judson U. McGuire, Jr.
12. If each field grows its manure, by M.S. Sivaraman.
13. Sampling and analysis of lowland rice soils in Malaya, by A.R. McWalter and G.W. Arnott.
14. Farmers' schools in China, by C.W. Chang.

#### Volume VII, No. 4 — December 1958

15. Green manure crops in relation to paddy rice production in South-east Asia, by Ernest V. Staker.
16. Rice seed multiplication and distribution in Taiwan, by H.S. Chang.
17. Brief report on the agricultural mechanization in Taiwan, by F.C. Ma.



18. Summary of Recommendations of the Sixth Session of the International Rice Commission.
19. Progress report on the work of the International Rice Commission, by C.W. Chang.

**Volume VIII, No. 1 — March 1959**

20. Fertilizer trials in cultivators' fields in Ceylon, by F.N. Ponnamperuma.
21. Improved rice seed production and distribution in Ceylon, by Loren L. Davis.
22. Storage loss of paddy due to Sitotroga Cerealella and its control, by H.E. Fernando.
23. The first pilot rice mill in Liberia, by M. Manni and T.T. Hogan.

**Volume VIII, No. 2 — June 1959**

24. The rice breeding program and its recent development in Taiwan, by H.S. Chang.
25. Production, certification and distribution of Ponlai rice seeds in Taiwan, by H.S. Chang.
26. Method and time of nitrogen application to rice, by C.T. Abichandani and S. Patnaik.
27. The need for rice varieties with wider adaptability, by N. Parthasarathy.
28. Review of "Japonica rice, its breeding and culture" by N. Parthasarathy.

**Volume VIII, No. 3 — September 1959**

29. Progress in weed control in rice production in the United States, by Roy J. Smith, Jr., K.L. Viste and W.C. Shaw.

30. Breeding rice varieties for resistance to the virus disease Hoja Blanca, by H.M. Beachell, N.E. Jodon, T.H. Johnston, J.R. Thysell, J.G. Atkins and H.A. Lamey.
31. Note on genom analysis in *Oryza* species, by Toshitaro Morinaga.
32. Some aspects of the physiology of bronzing, by Noboru Yamada.
33. Some problems on managing rice farms in Nakorn Pathom Province, Thailand, by Shao-er Ong, and Prayard Chandrapuang.

**Volume VIII, No. 4 — December 1959**

34. Genetic symbols for rice recommended by the International Rice Commission.
35. Practical purity and the method of maintenance of established varieties of rice, by Kan-Ichi Sakai.
36. The nature of fertilizer response in Japonica and Indica rice varieties, by Noboru Yamada.
37. A note on the analysis of the yield potential in the Indica hybrid, H-4, by Noboru Yamada.

**Volume IX, No. 1 — March 1960**

38. Review of investigations on physiological diseases of rice — 1, by J. Takahashi.
39. Method of reducing the number of varieties in Thailand, by Sala Dasananda.
40. Final report on the International Rice Hybridization Project, by N. Parthasarathy.
41. Summary report of 1959 Meetings of the Two Working Parties of the International Rice Commission.

## Volume IX, No. 2 — June 1960

42. Seed certification schemes for rice in various countries, by G. Julen and A. Kjaer.
43. Review of investigations into physiological diseases of rice — 2, by J. Takahashi.
44. A short note on the trial of some introduced paddy varieties at Himayatsagar, Andhra Pradesh, by M.S. Pawar, V.V.S. Murthy and P. Narahari.
45. Introducing the International Rice Research Institute, by P.C. Ma.

## Volume IX, No. 3 — September 1960

46. Ratoon cropping of short-season rice varieties in Texas, by N.S. Evatt and H.M. Beachell.
47. The response of short-strawed rice varieties to varying levels of nitrogen fertilization, by N.S. Evatt, T.H. Johnson and H.M. Beachell.
48. Rice in the Sudan, by R.L.M. Ghose and Yacoub El Sayegh.
49. A note on some irrigation practices in Taiwan, by Peter Kung.

50. Improvement of farming practice with special reference to flexible rice culture method, by Kaio Komoda.

## Volume IX, No. 4 — December 1960

51. Correlation between soil analyses and responses to fertilizers with special reference to rice crop in India, by R.V. Tamhane and B.V. Subbiah.
52. What fertilizers could do to increase world food production, by H.L. Richardson.
53. Rice in Thailand, by Sala Dasananda.
54. The cultivation of upland rice in rotation with groundnut in Senegal, by C. Magne.
55. Plans for Cooperative Variety Testing of Improved Rice Varieties with Wide Adaptation.
56. Announcement by the Director, Commonwealth Institute of Biological Control regarding specimens of oriental Neuropterous insects.

## SUBJECT INDEX, 1958-60

## 1. Rice Production

1. Natural cross-pollination in rice in Malaya (June 1958).
2. Rice seed multiplication and distribution in Taiwan (December 1958).
3. Improved rice seed production and distribution in Ceylon (March 1959).
4. The rice breeding program and its recent development in Taiwan (June 1959).
5. Production, certification and distribution of Ponlai rice seeds in Taiwan (June 1959).
6. The need for rice varieties with wider adaptability (June 1959).
7. Progress in weed control in rice production in the United States (September 1959).
8. Breeding rice varieties for resistance to the virus disease Hoja Blanca (September 1959).
9. Note on genom analysis in *Oryza* species (September 1959).



10. Genetic symbols for rice recommended by the International Rice Commission (December 1959).
11. Practical purity and the method of maintenance of established varieties of rice (December 1959).
12. The nature of fertilizer response in Japonica and Indica rice varieties (December 1959).
13. A note on the analysis of the yield potential in the Indica hybrid, H-4 (December 1959).
14. Method of reducing the number of varieties in Thailand (March 1960).
15. Final report on the International Rice Hybridization Project (March 1960).
16. Seed certification schemes for rice in various countries (June 1960).
17. A short note on the trial of some introduced paddy varieties at Himayatsagar, Andhra Pradesh (June 1960).
18. Ratoon cropping of short-season rice varieties in Texas (September 1960).
19. The response of short-strawed rice varieties to varying levels of nitrogen fertilization (September 1960).
20. Rice in the Sudan (September 1960).
21. Improvement of farming practice with special reference to flexible rice culture method (September 1960).
22. Rice in Thailand (December 1960).

23. The cultivation of upland rice in rotation with groundnut in Senegal (December 1960).
24. Plans for Cooperative Variety Testing of Improved Rice Varieties with Wide Adaptation (December 1960).

## 2. Rice Protection

1. Lime as a remedy for a physiological disease of rice associated with excess iron (March 1958).
2. The Hoja Blanca disease of rice (September 1958).
3. Storage loss of paddy due to *Sitotroga Cerealella* and its control (March 1959).
4. Some aspects of the physiology of bronzing (September 1959).
5. Review of investigations on physiological diseases of rice — 1 (March 1960).
6. Review of investigations into physiological diseases of rice — 2 (June 1960).

## 3. Rice Soils, Water and Fertilizer Practices

1. Rotational irrigation for rice — a revolution in Taiwan (March 1958).
2. Effects of water depth on the growth and yield of lowland rice (March 1958).
3. Time and methods of application of urea, (March 1958).
4. Paddy soils (June 1958).
5. If each field grows its manure (September 1958).
6. Sampling and analysis of lowland rice soils in Malaya (September 1958).

7. Green manure crops in relation to paddy rice production in Southeast Asia (December 1958).
  8. Fertilizer trials in cultivators' fields in Ceylon (March 1959).
  9. Method and time of nitrogen application to rice (June 1959).
  10. A note on some irrigation practices in Taiwan (September 1960).
  11. Correlation between soil analyses and responses to fertilizers with special reference to rice crop in India (December 1960).
  12. What fertilizers could do to increase world food production (December 1960).
4. **Agricultural Engineering Aspects of Rice Production, Storage and Processing.**
1. Brief report on the agricultural mechanization in Taiwan (December 1958).
  2. The first pilot rice mill in Liberia (March 1959).
5. **General**
1. Impressions of agricultural extension work in the United States of America (March 1958).
  2. Review of "Rice in India" (March 1958).
  3. Agricultural extension in Asia (June 1958).
  4. The Sixth Session of the International Rice Commission (June 1958).
  5. Farmers' schools in China (September 1958).
  6. Summary of Recommendations of the Sixth Session of the International Rice Commission (December 1958).
  7. Progress report on the work of the International Rice Commission (December 1958).
  8. Review of "Japonica rice, its breeding and culture" (June 1959).
  9. Some problems on managing rice farms in Nakorn Pathom Province, Thailand (September 1959).
  10. Summary report of 1959 Meetings of the Two Working Parties of the International Rice Commission (March 1960).
  11. Introducing the International Rice Research Institute (June 1960).
  12. Announcement by the Director, Commonwealth Institute of Biological Control regarding specimens of oriental Neuropterous insects (December 1960).

### AUTHOR INDEX, 1958-60

Abichandani, C.T. and Patnaik, S.

Method and time of nitrogen application to rice (June 1959).

Atkins, John G. and McGuire, Judson U. Jr.

The Hoja Blanca disease of rice (September 1958),

Beachell, H.M., Jodon, N.E., Johnston, T.H.,  
Thysell, J.R., Atkins J.G. and Lamey, H.A.

Breeding rice varieties for resistance to the virus disease Hoja Blanca (September 1959).

Brown, F.B.

Natural cross-pollination in rice in Malaya (June 1958).



**Bulanadi, Julian and Aldaba, Primo B.**

Effects of water depth on the growth and yield of lowland rice ( March 1958 ).

**Chang, C.W.**

Impressions of agricultural extension work in the United States of America ( March 1958 ).

Agricultural extension in Asia ( June 1958 ).

Farmers' schools in China ( September 1958 ).

Progress report on the work of the International Rice Commission ( December 1958 ).

**Chang, H.S.**

Rice seed multiplication and distribution in Taiwan ( December 1958 ).

The rice breeding program and its recent development in Taiwan ( June 1959 ).

Production, certification and distribution of Ponlai rice seeds in Taiwan ( June 1959 ).

**Chow, Lee**

Rotational irrigation for rice - a revolution in Taiwan ( March 1958 ).

**Dasananda, Sala**

Method of reducing the number of varieties in Thailand ( March 1960 ).

Rice in Thailand ( December 1960 ).

**Davis, Loren L.**

Improved rice seed production and distribution in Ceylon ( March 1959 ).

**Dudal, R.**

Paddy Soils ( June 1958 ).

**Evatt, N.S. and Beachell, H.M.**

Ratoon cropping of short-season rice varieties in Texas ( September 1960 ).

**Evatt, N.S., Johnson, T.H. and Beachell, H.M.**

The response of short-strawed rice varieties to varying levels of nitrogen fertilization ( September 1960 ).

**Fernando, H.E.**

Storage loss of paddy due to *Sitotroga Cerealella* and its control ( March 1959 ).

**Ghose, R.L.M. and Yacoub El Sayegh**

Rice in the Sudan ( September 1960 )

**Julen, G. and Kjaer, A.**

Seed certification schemes for rice in various countries ( June 1960 ).

**Komoda, Kaio**

Improvement of farming practice with special reference to flexible rice culture method ( September 1960 ).

**Kung, Peter**

A note on some irrigation practices in Taiwan ( September 1960 ).

**Ma, F.C.**

Brief report on the agricultural mechanization in Taiwan ( December 1958 ).

**Ma, P.C.**

Introducing the International Rice Research Institute ( June 1960 ).

**Magne, C.**

The cultivation of upland rice in rotation with groundnut in Senegal ( December 1960 ).

**Manni, M. and Hogan, T.T.**

The first pilot rice mill in Liberia ( March 1959 ).

**McWalter, A.R. and Arnott, G.W.**

Sampling and analysis of lowland rice soils in Malaya (September 1958).

**Morinaga, Toshitaro**

Note on genom analysis in *Oryza* species (September 1959).

**Ong, Shao-er and Chandrapuang, Prayard**

Some problems on managing rice farms in Nakorn Pathom Province, Thailand (September 1959).

**Parthasarathy, N.**

Review of "Rice in India" (March 1958).

The need for rice varieties with wider adaptability (June 1959).

Review of "Japonica rice, its breeding and culture" (June 1959).

Final report on the International Rice Hybridization Project (March 1960).

**Pawar, M.S., Murthy, V.V.S., and Narahari, P.**

A short note on the trial of some introduced paddy varieties at Himayatsagar, Andhra Pradesh (June 1960).

**Ponnamperuma, F.N.**

Lime as a remedy for a physiological disease of rice associated with excess iron (March 1958).

Fertilizer trials in cultivators' fields in Ceylon (March 1959).

**Richardson, H.L.**

What fertilizers could do to increase world food production (December 1960).

**Sakai, Kan-Ichi**

Practical purity and the method of maintenance of established varieties of rice (December 1959).

**Sivaraman, M.S.**

If each field grows its manure (September 1958).

**Staker, Ernest V.**

Green manure crops in relation to paddy rice production in Southeast Asia (December 1958).

**Smith, J. Jr., Viste, K.L. and Shaw, W.C.**

Progress in weed control in rice production in the United States (September 1959).

**Takahashi, J.**

Review of investigations on physiological diseases of rice - 1 (March 1960).

Review of investigations into physiological diseases of rice - 2 (June 1960).

**Tamhane, R.V. and Subbiah, B.V.**

Correlation between soil analyses and responses to fertilizers with special reference to rice crop in India (December 1960).

**Yamada, Noboru**

Some aspects of the physiology of bronzing (September 1959).

The nature of fertilizer response in Japonica and Indica rice varieties (December 1959).

A note on the analysis of the yield potential in the Indica hybrid, H-4 (December 1959).



Sakai, Masahiko

Practical purity and the method of maintenance of established varieties of rice (December 1959).

Silverman, M.S.

If each field grows its measure (September 1958).

Slater, Ernest V.

Green measure crops in relation to paddy rice production in Southeast Asia (December 1958).

Smith, J. W., Viste, K.L. and Shaw, W.C.

Progress in weed control in rice production in the United States (September 1959).

Takahashi, J.

Review of investigations on physiological diseases of rice - I (March 1960).

Review of investigations on physiological diseases of rice - II (June 1960).

Tamhane, H.V. and Soodhak, H.V.

Correlation between soil analysis and response to fertilizers with special reference to rice crop in India (December 1960).

Yamada, Noboru

Some aspects of the physiology of breeding (September 1958).

The nature of fertilizer response in Japanese and Indian rice varieties (December 1959).

A note on the analysis of the yield potential in the Indian hybrid H-4 (December 1959).

McWalter, A.R. and Atwell, G.W.

Sampling and analysis of lowland rice soils in Malaya (September 1958).

Mohtaseb, Tashkara

Notes on genomic analysis in Oryza species (September 1959).

Gop, Shas-er and Chandra-singh, Prayag

Agro-ecological problems in rice-growing areas in Madhya Pradesh, India (September 1959).

Parthasarathy, N. and Sankar, N. S.

Review of "Rice in India" (March 1958).

The need for rice varieties with wider adaptability (June 1959).

Review of "Japanese rice, its growth and culture" (June 1959).

Final report on the International Rice Hybridization Project (March 1960).

Tewari, M.S., Murthy, V.V.S. and Narasimha, K.

A short note on the trial of some introduced paddy varieties at Hyderabad, Andhra Pradesh (June 1960).

Ponnamparman, P.N.

Time as a remedy for a physiological disease of rice associated with excess water (March 1958).

Fertilizer trials in cultivators' fields in Orissa (March 1959).

Richardson, H.L.

What fertilizers could do to increase world food production (December 1960).





